CORRELATION AND MULTIPLE REGRESSION

Introduction

Children are exposed to a plethora of social and academic challenges from their early school days when building friendships and maintaining institution regulations become salient in their lives. Various cognitive abilities contribute to making this adaptation a successful one; some relevant developmental concepts that interplay are theory of mind (ToM), executive function and verbal ability.

ToM is a complex cognitive ability which facilitates the distinction between the beliefs of the self and of others; it is a key part of social interaction given its role in interpreting the behaviours and mental states of others (Premack & Woodruff, 1978). An example of the assessment of simple theory of mind (sToM) at the basic level is the first-order false-belief task whereby the location of an object is stored within the knowledge of a character and then hidden without the character knowing; the child is then asked to infer the character's perception of the object's location e.g. "John thinks that…" (Wimmer & Perner, 1983). As children progress through childhood and their ToM develops, they are able to perform the more complex second-order false-belief tasks (advanced theory of mind [aToM]). A typical example of this is when a child is asked to determine what one character thinks about another character's beliefs e.g. "John thinks that Mary thinks that.." (Wimmer & Perner, 1985).

Research has disseminated a robust link between ToM and executive function (EF), a combination of processes such as attention, updating of working memory, inhibition, goal-directed behaviour and problem-solving – assessed by administering a series of tasks (Anderson, 2001). Some studies have noted the emergence of EF to be dependent on ToM (Devine & Hughes, 2014), whereas other authors have found the opposite (Kouklari, Tsermentseli & Auyeung, 2018).

It was proposed that the relationship between ToM and EF have differences in cognitive attributes (Hughes, 1998) such as verbal ability, which is commonly measured using the British Picture Vocabulary Scale. A study (Hughes & Ensor, 2007) found that verbal ability predicted EF but not ToM, whereas, a twin-study noted a strong association between verbal ability and ToM (Ronald et al., 2007).

Whilst the evidence on this topic seem to provide conflicting research, it can be agreed that verbal ability, EF and ToM are related in childhood development. This report aims to conduct

statistical analyses on these variables to ascertain their relationship, predict their outcomes, and provide support to one or more of the proposals discussed in previous literature.

Results

The dataset was scanned for anomalies via boxplots; none of the entries were eliminated to prevent loss of large amounts of data. The sample consisted of pre-schoolers (mean age = 5.99, SD = .43, 57% male).

Given the non-parametric distribution of the data, Spearman's correlations were conducted to identify the relationships between various variables including executive function, BPVS scores and simple and advanced ToM (Table 1).

Executive function indicated a significantly positive (moderate) correlation with sToM ($r(292) = .42$, p = .001), aToM ($r(292) = .36$, p = .001) and verbal ability ($r(289) = .45$, p = .001). Simple ToM also indicated a significantly positive (strong) relationship with advanced ToM ($r(292) = .69$, p = .001) and verbal ability ($r(289) = .50$, p = .001). Additionally, a positive (strong) correlation was observed between aToM and verbal ability ($r(289) = .53$, p = .001).

Table 1.

Descriptive Statistics and Spearman Correlations of Variables.

Measure	*N*	*M(SD)*[a]	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1. Age	293	5.99 (.43)	-						
2. EF	294	-.003 (.63)	.36**	-					
3. Simple ToM	294	5.24 (1.45)	.14*	.42**	-				
4. Advanced ToM	294	4.30 (2.56)	.22**	.36**	.69**	-			
5. Verbal ability	291	54.80 (13.97)	.29**	.45**	.50**	.53**	-		
6. Dweck Emotion	293	.95 (.77)	-.02	.04	.09	.003	-.01	-	
7. Dweck Ability	293	.59 (.78)	.07	-.09	-.02	-.07	-.14*	.27**	-

Note. ToM (Theory of Mind), EF (Executive Function).

*p<.05; **p<.01

The variables of interest had significant associations. To examine their possible predictive relationships, the data was then entered into a hierarchical multiple linear regression with aToM as the outcome, and the predictors being sToM (first step), executive function (second step) and verbal ability (third step). The three models were all significant overall [Model 1:

F(1, 289) = 242.56, p = .001); Model 2: F(1, 288) = 123.32, p = .001); Model 3: F(1, 287) = 92.52, p = .001]. Verbal ability and sToM were both significant in the steps they were entered. Executive function, however, was not significant when entered in the second and third steps (see Table 2).

Table 2.

Hierarchical multiple regression for variables predicting advanced ToM.

Variable	B	S.E. *B*	*β*	*t*
Step 1				
Simple ToM	1.19	.08	.68	15.57**
Step 2				
Simple ToM	1.13	.09	.64	13.21**
EF	.32	.20	.08	1.64
Step 3				
Simple ToM	.97	.09	.55	10.69**
EF	.09	.20	.02	.45
Verbal ability	.04	.01	.21	4.14**

Note. ToM (Theory of Mind), EF (executive function).

R^2 = .46 for Step 1, ΔR^2 = .005 for Step 2, ΔR^2 = .03 for Step 3.

*p<.05; **p<.01

SECTION TWO: MODERATION

Introduction

It has been established that ToM facilitates the transition of pre-school children via EF and verbal ability (Brock et al., 2018). To further the understanding of the interaction of these variables, a study exploring the stability of EF in pre-schoolers found that their EF scores improved overtime and, interestingly, their verbal ability significantly predicted changes in EF (Fuhs & Day, 2011). Given that EF did not predict ToM previously, it would be of interest to explore whether their findings are sustained in this sample. The interaction of verbal ability, EF and age will be explored to examine the relationship between these variables.

Results

A linear model was conducted with executive function as the outcome, verbal ability as the predictor and age as the moderator. The overall model was significant (F(3, 286) = 22.95, p =

.001), as well as the predictor and moderator. The interaction, however, was not significant (see table 3).

Table 3.

Executive function as predicted by verbal ability and age, and the associated interaction.

	b	S.E. *B*	*t*	*p*
Constant	.01	.03	.31	.76
Verbal ability	.02	.00	5.87	.001
Age	.31	.10	3.18	.001
Verbal ability x Age	-.01	.01	-.47	.64

R^2 = .25.

Conclusion

Both sToM and aToM, EF and verbal ability were significantly correlated with each other. Given that sToM is the prerequisite for aToM development, it was confirmed that the former predicts the latter the most, with EF contributing the least variance to this prediction. Whilst verbal ability and age were independently significant predictors of EF, their interaction did not have a moderating effect on EF. These analyses reflect the findings of previous research (Hughes & Ensor, 2007; Fuhs & Day, 2011), in that verbal ability predicts EF in preschool children but the cognitive skill is not sufficient in explaining the variation in ToM. However, it is worth noting that these results can only be applied to the population the sample was extracted from as the development of these skills differ across cultures; for example, children in Hong Kong showed a delayed development of ToM at this age compared to their British counterparts but outperformed the latter in executive function tasks (Wang et al., 2016). These skills are indeed intertwined and influence the transition challenges children face at school as a result.

References

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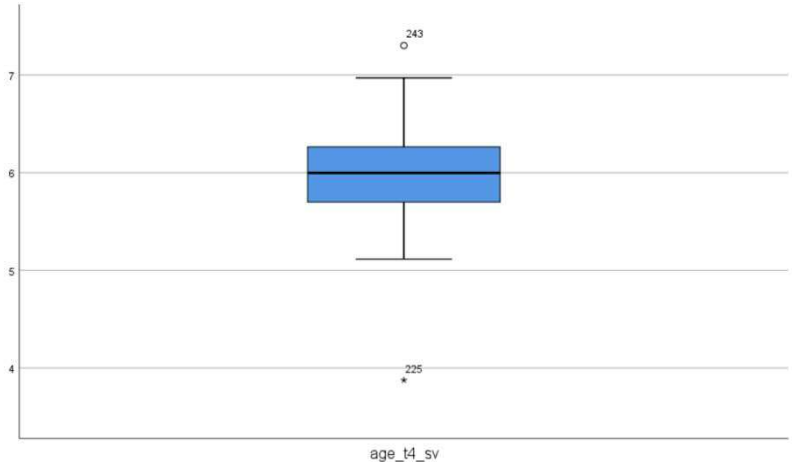
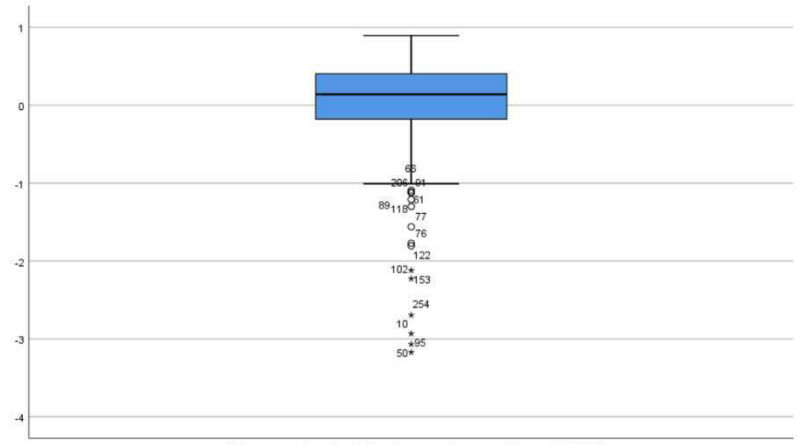
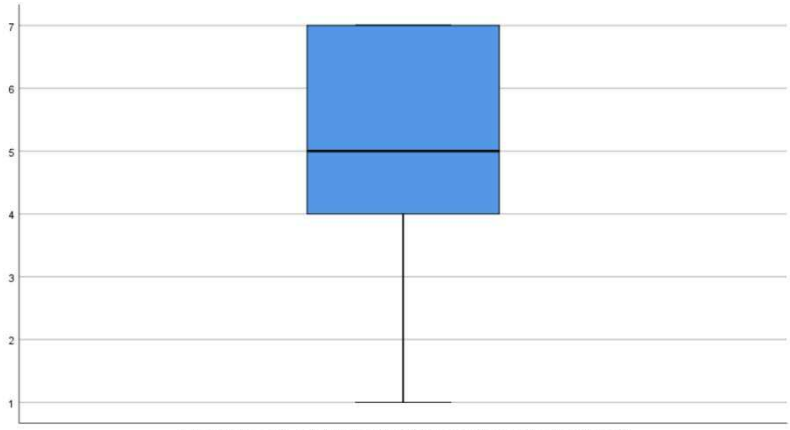
APPENDICES

Appendix 1 – Screening data

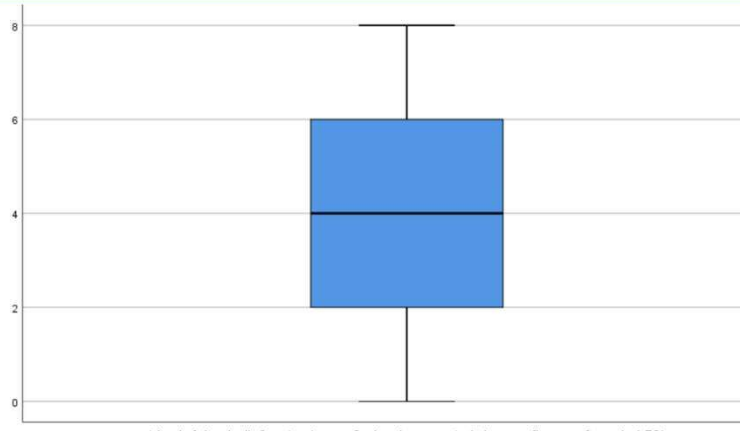




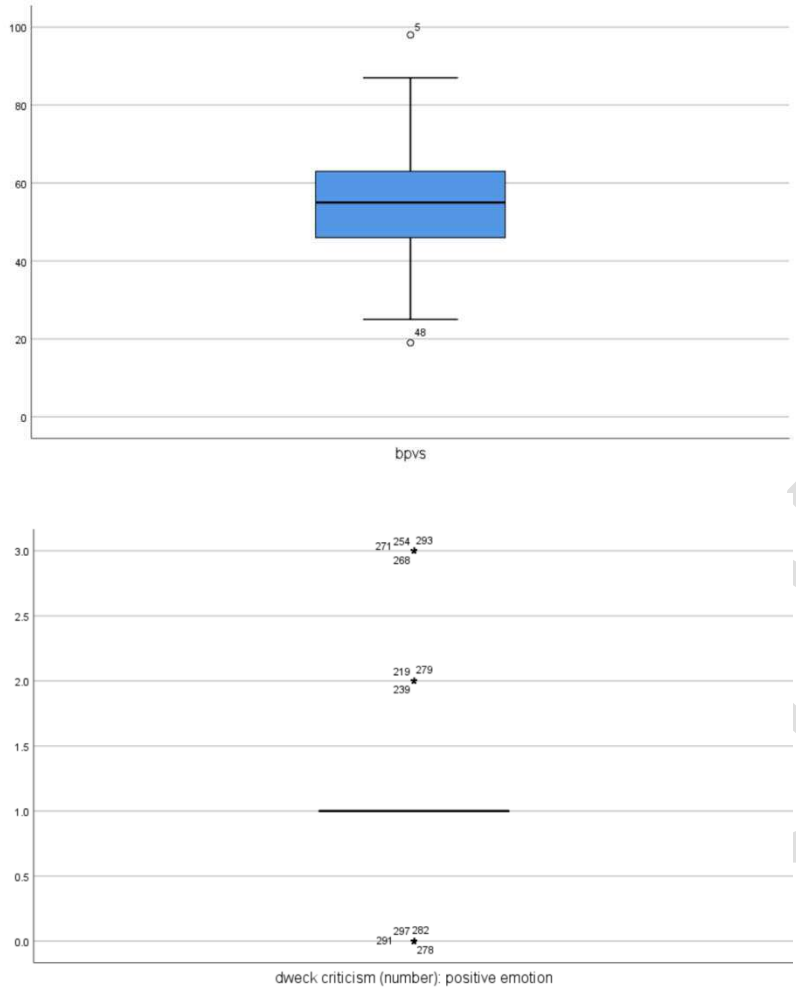
ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)



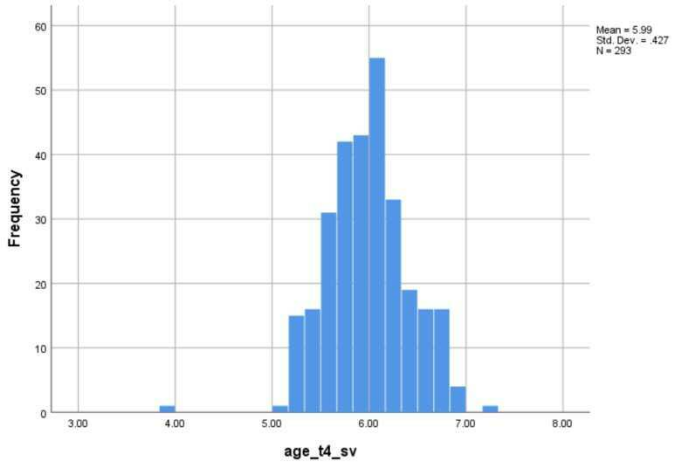
1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)

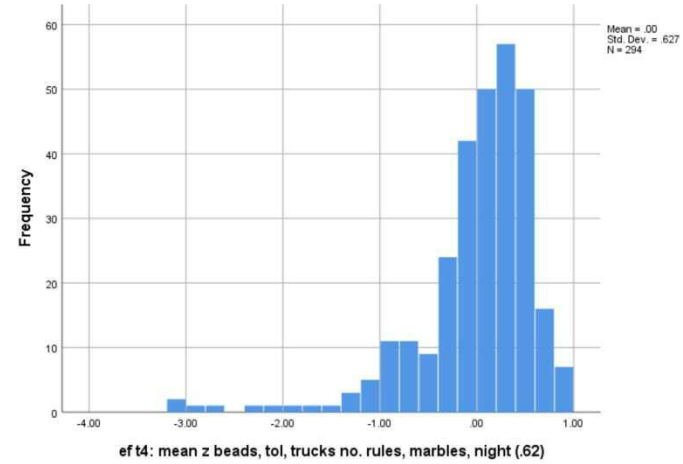


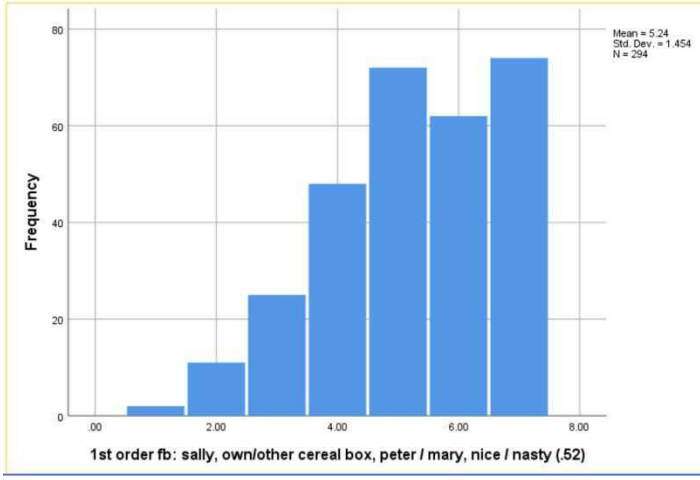
t4 adv false-belief: peter / mary 2nd order + nasty / nice em fb ques & expln (.79)



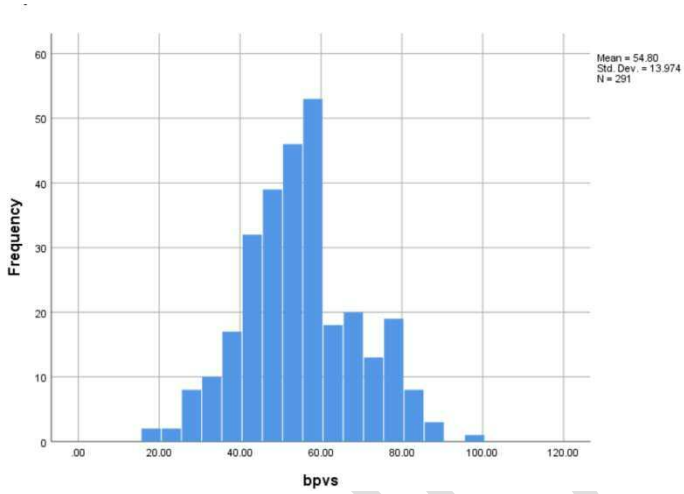
Appendix 2 – Histograms indicating non-parametric data

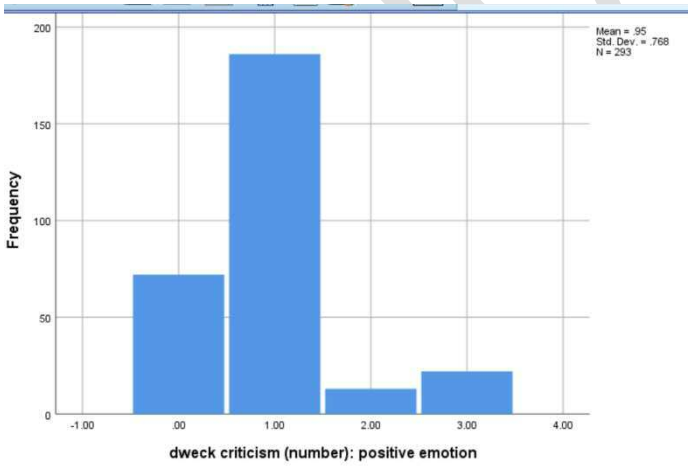

Mean = 5.99
Std. Dev. = .427
N = 293
Frequency
age_t4_sv

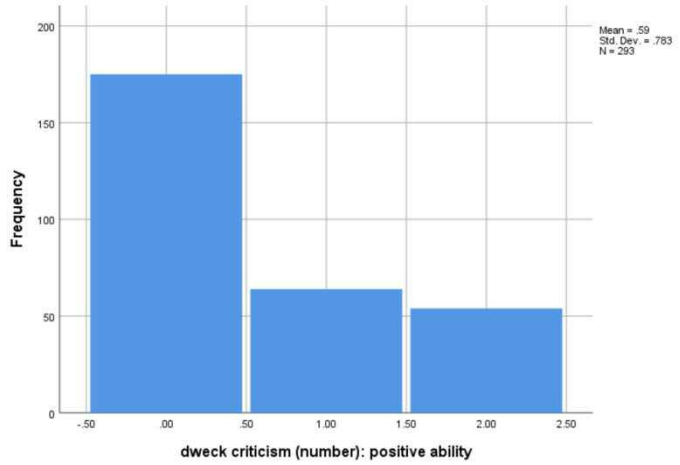

Mean = .00
Std. Dev. = .627
N = 294
Frequency
ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)


Mean = 5.24
Std. Dev. = 1.454
N = 294
Frequency
1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)


Mean = 4.30
Std. Dev. = 2.558
N = 294
Frequency
t4 adv false-belief: peter / mary 2nd order + nasty / nice em fb ques & expln (.79)


Mean = 54.80
Std. Dev. = 13.974
N = 291
Frequency
bpvs


Mean = .95
Std. Dev. = .768
N = 293
Frequency
dweck criticism (number): positive emotion



Appendix 3 – Descriptive statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
age_t4_sv	293	3.88	7.30	5.9883	.42730
gender	297	1.00	2.00	1.4343	.49651
ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)	294	-3.17	.90	-.0034	.62686
1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)	294	1.00	7.00	5.2415	1.45449
t4 adv false-belief: peter / mary 2nd order + nasty / nice em fb ques & expln (.79)	294	.00	8.00	4.2959	2.55803
bpvs	291	18.00	98.00	54.8007	13.97367
dweck criticism (number): positive emotion	293	.00	3.00	.9488	.76801
dweck criticism (number): positive ability	293	.00	2.00	.5870	.78302
Valid N (listwise)	289				

GET

Appendix 4 – Spearman's correlation

Correlations

			age_t4_sv	gender	ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)	1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)	t4 adv false-belief: peter / mary 2nd order + nasty / nice em fb ques & expln (.79)	bpvs	dweck criticism (number): positive emotion	dweck criticism (number): positive ability
Spearman's rho	age_t4_sv	Correlation Coefficient	1.000	-.011	.358**	.137*	.229**	.289**	-.023	.066
		Sig. (2-tailed)	.	.856	.000	.019	.000	.000	.692	.259
		N	293	293	293	293	293	290	292	292
	gender	Correlation Coefficient	-.011	1.000	.001	-.022	.040	-.023	-.034	-.015
		Sig. (2-tailed)	.856	.	.991	.711	.495	.695	.562	.799
		N	293	297	294	294	294	291	293	293
	ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)	Correlation Coefficient	.358**	.001	1.000	.420**	.360**	.454**	.042	-.092
		Sig. (2-tailed)	.000	.991	.	.000	.000	.000	.475	.116
		N	293	294	294	294	294	291	293	293
	1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)	Correlation Coefficient	.137*	-.022	.420**	1.000	.693**	.503**	.085	-.024
		Sig. (2-tailed)	.019	.711	.000	.	.000	.000	.149	.682
		N	293	294	294	294	294	291	293	293
	t4 adv false-belief: peter / mary 2nd order + nasty / nice em fb ques & expln (.79)	Correlation Coefficient	.229**	.040	.360**	.693**	1.000	.529**	.003	-.065
		Sig. (2-tailed)	.000	.495	.000	.000	.	.000	.964	.265
		N	293	294	294	294	294	291	293	293
	bpvs	Correlation Coefficient	.289**	-.023	.454**	.503**	.529**	1.000	-.011	-.139*
		Sig. (2-tailed)	.000	.695	.000	.000	.000	.	.851	.018

Spearman's rho	age_t4_sv	Correlation Coefficient	1.000	-.011	.358	.137	.229	.289	-.023	.066
		Sig. (2-tailed)	.	.856	.000	.019	.000	.000	.692	.259
		N	293	293	293	293	293	290	292	292
	gender	Correlation Coefficient	-.011	1.000	.001	-.022	.040	-.023	-.034	-.015
		Sig. (2-tailed)	.856	.	.991	.711	.495	.695	.562	.799
		N	293	297	294	294	294	291	293	293
	ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)	Correlation Coefficient	.358**	.001	1.000	.420**	.360**	.454**	.042	-.092
		Sig. (2-tailed)	.000	.991	.	.000	.000	.000	.475	.116
		N	293	294	294	294	294	291	293	293
	1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)	Correlation Coefficient	.137*	-.022	.420**	1.000	.693**	.503**	.085	-.024
		Sig. (2-tailed)	.019	.711	.000	.	.000	.000	.149	.682
		N	293	294	294	294	294	291	293	293
	t4 adv false-belief: peter / mary 2nd order + nasty / nice em fb ques & expln (.79)	Correlation Coefficient	.229**	.040	.360**	.693**	1.000	.529**	.003	-.065
		Sig. (2-tailed)	.000	.495	.000	.000	.	.000	.964	.265
		N	293	294	294	294	294	291	293	293
	bpvs	Correlation Coefficient	.289**	-.023	.454**	.503**	.529**	1.000	-.011	-.139*
		Sig. (2-tailed)	.000	.695	.000	.000	.000	.	.851	.018
		N	290	291	291	291	291	291	290	290
	dweck criticism (number): positive emotion	Correlation Coefficient	-.023	-.034	.042	.085	.003	-.011	1.000	.265**
		Sig. (2-tailed)	.692	.562	.475	.149	.964	.851	.	.000
		N	292	293	293	293	293	290	293	293
	dweck criticism (number): positive ability	Correlation Coefficient	.066	-.015	-.092	-.024	-.065	-.139*	.265**	1.000
		Sig. (2-tailed)	.259	.799	.116	.682	.265	.018	.000	.
		N	292	293	293	293	293	290	293	293

Appendix 5 – Hierarchical multiple regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.676[a]	.456	.454	1.88590	.456	242.555	1	289	.000
2	.679[b]	.461	.458	1.88044	.005	2.681	1	288	.103
3	.701[c]	.492	.486	1.82993	.030	17.117	1	287	.000

a. Predictors: (Constant), 1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)

b. Predictors: (Constant), 1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52), ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)

c. Predictors: (Constant), 1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52), ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62), bpvs

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	862.678	1	862.678	242.555	.000[b]
	Residual	1027.865	289	3.557		
	Total	1890.543	290			
2	Regression	872.158	2	436.079	123.323	.000[c]
	Residual	1018.385	288	3.536		
	Total	1890.543	290			
3	Regression	929.479	3	309.826	92.523	.000[d]
	Residual	961.064	287	3.349		
	Total	1890.543	290			

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.913	.415		-4.613	.000
	1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)	1.188	.076	.676	15.574	.000
2	(Constant)	-1.584	.460		-3.444	.001
	1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)	1.125	.085	.640	13.211	.000
	ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)	.321	.196	.079	1.637	.103
3	(Constant)	-2.918	.552		-5.290	.000
	1st order fb: sally, own/other cereal box, peter / mary, nice / nasty (.52)	.971	.091	.552	10.687	.000
	ef t4: mean z beads, tol, trucks no. rules, marbles, night (.62)	.090	.199	.022	.454	.650
	bpvs	.039	.009	.214	4.137	.000

a. Dependent Variable: t4 adv false-belief: peter / mary 2nd order + nasty / nice em fb ques & expln (.79)

Appendix 6 – Moderation analysis

```
Sample
Size:  290

**************************************************************************
OUTCOME VARIABLE:
 EF

Model Summary
          R       R-sq        MSE      F(HC3)        df1        df2          p
      .5036      .2536      .2993     22.9545     3.0000   286.0000      .0000

Model
              coeff    se(HC3)          t          p       LLCI       ULCI
constant      .0097      .0312      .3120      .7553     -.0517      .0712
bpvs          .0178      .0030     5.8654      .0000      .0118      .0238
Age           .3116      .0980     3.1805      .0016      .1188      .5045
Int_1        -.0054      .0115     -.4675      .6405     -.0281      .0173

Product terms key:
 Int_1    :        bpvs     x        Age

Test(s) of highest order unconditional interaction(s):
       R2-chng      F(HC3)        df1        df2          p
X*W      .0031      .2185     1.0000   286.0000      .6405
----------
    Focal predict: bpvs      (X)
          Mod var: Age       (W)
```

```
Data for visualizing the conditional effect of the focal predictor:
Paste text below into a SPSS syntax window and execute to produce plot.

DATA LIST FREE/
   bpvs       Age        EF         .
BEGIN DATA.
   -13.9931     -.4291     -.4055
      .0000     -.4291     -.1240
    13.9931     -.4291      .1576
   -13.9931      .0000     -.2395
      .0000      .0000      .0097
    13.9931      .0000      .2589
   -13.9931      .4291     -.0734
      .0000      .4291      .1434
    13.9931      .4291      .3603
END DATA.
GRAPH/SCATTERPLOT=
 bpvs     WITH     EF       BY       Age      .

************************ ANALYSIS NOTES AND ERRORS ************************

Level of confidence for all confidence intervals in output:
  95.0000

NOTE: A heteroscedasticity consistent standard error and covariance matrix estimator was used.

NOTE: The following variables were mean centered prior to analysis:
```

Double-click to activate